Glass and Ceramics, Vol. 68, Nos. 5 – 6, September, 2011 (Russian Original, Nos. 5 – 6, May – June, 2011)

UDC 666.3:535.345

TRANSPARENT CERAMIC BASED ON YTTRIUM OXIDE WITH SCANDIUM OXIDE AND NEODYMIUM OXIDE ADDITIONS

N. A. Makarov,[1] D. O. Lemeshev,[1, 2] and K. I. Ikonnikov[1]

Translated from *Steklo i Keramika*, No. 6, pp. 24 – 26, June, 2011.

The possibility of obtaining a transparent ceramic material based on yttrium oxide with scandium oxide and neodymium oxide additions is investigated. The heat-treatment regimes for the mix and vacuum kilning are determined. A transparent ceramic material with direct phototransmission index 68% in the visible region of the spectrum and 1800°C sintering temperature is obtained.

Key words: transparent ceramic, yttrium oxide, scandium oxide, neodymium oxide.

Transparent ceramic has extensive promise for applications in various fields of technology. It can replace glass in devices operating under night-vision conditions [1, 2], at high temperatures, and in corrosive media. Transparent ceramic can be used for lenses of high-temperature microscopes, as reinforcement for special lamps [4, 5], and lenses for phototechnology. Ceramic based on yttrium oxide is transparent in the visible and infrared regions of the spectrum. After doping with rare-earth ions (terbium, neodymium, erbium, and samarium) its properties become close to the corresponding single crystals, which enables its use in laser technology.

In this work, the possibility of obtaining transparent ceramic materials based on yttrium oxide with scandium oxide addition is investigated. The initial components were yttrium carbonate and scandium chloride. $Y_2(CO_3)_3$ was synthesized by inverse heterophase deposition of $YCl_3 \cdot 6H_2O$ in a cooled $(NH_4)_2CO_3$ solution. Data from microscopic analysis showed that the powder consists of particles with average size 1 μm. The particles are combined into loose agglomerates 2 – 5 μm in size (Fig. 1). According to XPA, after synthesis the powder consists of one phase — yttrium carbonate (Fig. 2).

[1] D. I. Mendeleev Russian Chemical Technology University, Moscow, Russia.
[2] E-mail: diolem@gmail.com.

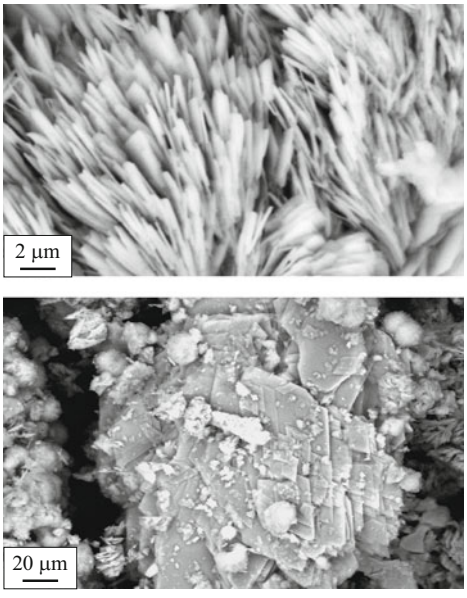

Fig. 1. Photograph of yttrium carbonate microstructure.

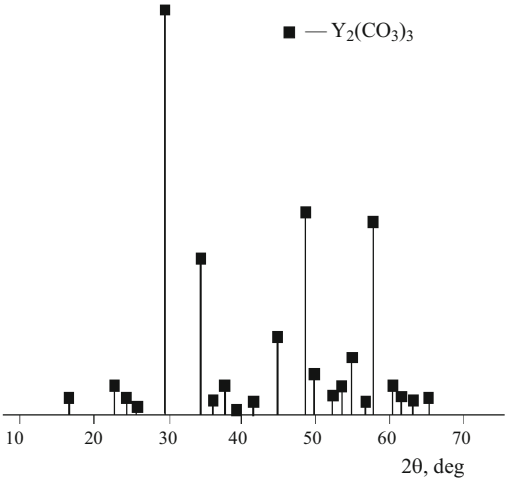

Fig. 2. X-ray diffraction pattern of $Y_2(CO_3)_3$ powder after precipitation.

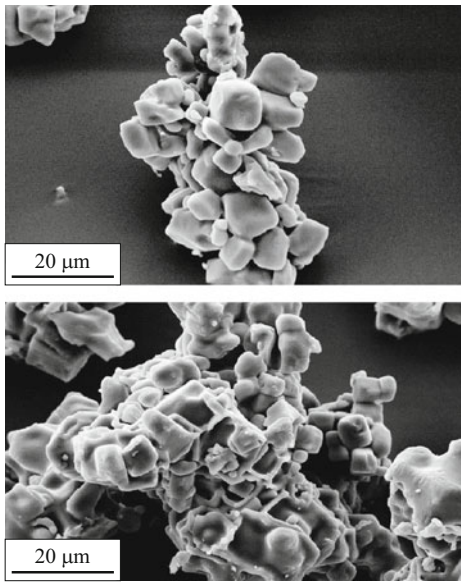

Fig. 3. Photograph of the microstructure of scandium chloride.

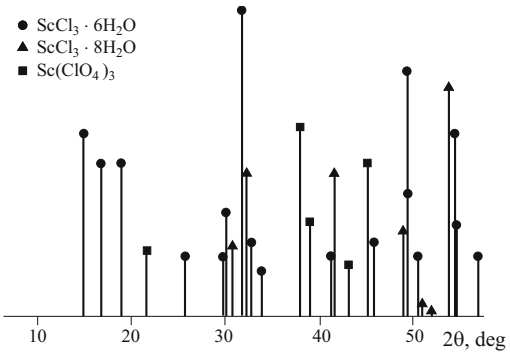

Fig. 4. X-ray diffraction pattern of $ScCl_3$ powder after synthesis.

Scandium chloride used as an additive was obtained by the chemical method:

$$Sc_2O_3 + 6HCl + nH_2O \rightarrow 2ScCl_3 \cdot nH_2O.$$

According to petrographic analysis, the powder $ScCl_3 \cdot nH_2O$ consists of isometric particles partially combined into loose aggregates. The particles aggregate sizes are 1 – 3 μm and 5 – 10 μm, respectively (Fig. 3). According to the XPA data and petrographic analysis, the powder consists of three crystalline phases: scandium chloride with different content of water in the crystal hydrate and negligible content of scandium chloride (Fig. 4).

The amount of $ScCl_3$ introduced with respect to $Y_2(CO_3)_3$ was 20%[3] in terms of oxide. Neodymium oxide was introduced in the amount 1% (above 100%) through its soluble salt $Nd(NO_3)_3$ into the mix of this material. The samples in the form of 32 mm in diameter disks and 30 × 40 mm plates

[3] Here and below — content by weight.

Fig. 5. Photograph of the polished surface of the samples (optical microscope). Thermal etching. ×210.

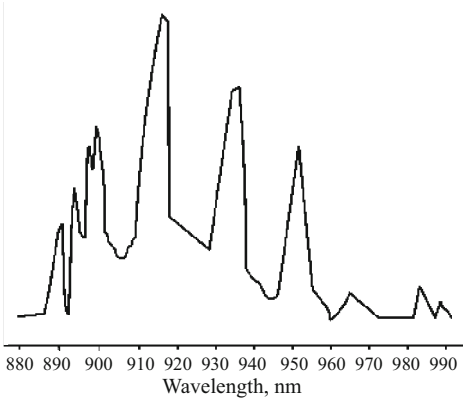

Fig. 6. Luminescence spectra of Nd^{3+}.

were formed by semi-dry pressing. The pressing pressure was 100 MPa. A 2.5% solution of polyvinyl alcohol was used as a temporary process binder; it was introduced in the amount 15 – 20% of the mass of the mix. After formation the binder was removed from the samples in an electric resistance furnace in the temperature interval 1000 – 1400°C. As the heat-treatment temperature increased, the phase composition of the material and the shape and size of the grains changed.

The samples were kilned in a vacuum furnace at final temperature 1750 – 1850°C. After kilning in vacuum "clarifying" kilning in air at temperature 1000°C was used to increase the transparency of the samples.

The microstructure of the ceramic obtained is shown in Fig. 5.

The luminescence spectrum (Fig. 6) obtained at room temperature confirms that the activators in the ceramic matrix are in a trivalent state. The phototransmission of the samples is 68% (Fig. 7).

Thus, an optically transparent ceramic in the system $Y_2O_3 – Sc_2O_3$ with neodymium oxide addition was obtained. Petrographic studies showed that the crystals are uniform with respect to the index of refraction. The size of the crystals is 1 – 3 μm. In all probability, neodymium oxide forms a

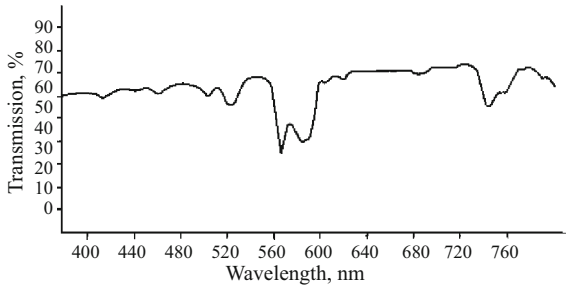

Fig. 7. Phototransmission spectrum of the samples.

solid solution with yttrium oxide and scandium oxide that retards crystal growth in the material. The lattice distortions of the solid solutions are expressed in the ubiquitous anomalous interference colors. The spectral and luminescence characteristics of the material obtained were determined — the absorption bands, predominately used to excite atoms and transferring them to a higher energy level: 560 – 600 nm for Nd^{3+}. The luminescence of ceramic containing neodymium ions is observed in the range 890 – 950 nm. This suggests that such a material can be used in laser technology and in technology using cathodic luminescence.

REFERENCES

1. US Patent 1974505206, H01S3/094; H01S3/16; (IPC1-7); H01S3/16, *High Energy Storage Lasers Employing Perovskites Containing Rare Earths.*
2. Isukuda Yusuo and Muta Akinori, "Sintering of Y_2O_3 at high temperatures," *J. Ceram. Soc. Jpn*., **84**(976), 585 – 589 (1976).
3. D. Weid, "Ceramics," in: *Proc. 1st and 2nd Conferences of the British and Dutch Ceramic Societies* [in Russian], Metallurgiya, Moscow (1967).
4. G. N. Rokhlin, and E. B. Volochkova, "High-pressure sodium lamps in ceramic envelopes," *Svetotekhnika*, No. 12, 14 (1971).
5. US Patent US3243635 (A), C04B37/02; H01J17/04; H01J5/32; H01J61/36, *Ceramic Lamp Construction.*